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COLLEGE STATION, BRAZOS COUNTY, TEXAS

BULLETIN NO. 355 MAY, 1927

DIVISION OF CHEMISTRY

RELATION OF THE POTASH REMOVED BY CROPS TO THE ACTIVE, TOTAL, ACID-SOLUBLE, AND ACID-INSOLUBLE POTASH OF THE SOIL

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SYNOPSIS

The object of this Bulletin is to trace the relation between the analysis of the soil for potash in several forms, and the amounts of potash taken up by plants in pot experiments, for the purpose of aiding in the interpretation of the results of soil analyses. The active potash, the total potash, the acid-soluble potash and the acid-insoluble potash are studied. The amount of active potash is found to be more closely related to the results of the pot tests than are any of the other forms of potash, though all have some relation both to the pot tests and to one another. The estimation of active potash is believed to give the best idea of the possible deficiency of the soil for potash at the present time. Statistical methods are used in the discussion.

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BULLETIN No. 355 MAY, 1927

RELATION OF THE POTASH REMOVED BY CROPS TO THE ACTIVE, TOTAL, ACID-SOLUBLE, AND ACID-INSOLUBLE POTASH OF THE SOIL

G. S. FRAPS

This Bulletin is a report of progress on a study of the relation between the chemical analysis of the soil and the properties of the soil. Previous bulletins have reported work on phosphoric acid, nitrogen, and potash and the results secured have been applied in other bulletins dealing with the composition and properties of typical Texas soils.

This Bulletin is one of the series dealing with soil potash. Bulletin 145 discusses the active potash of the soil and its relation to pot experiments; Bulletin 190, the effect of additions on the availability of soil potash; Bulletin 284, the availability of potash in some soil-forming minerals; Bulletin 325, the effect of cropping upon the active potash of the soil.

This Bulletin deals with the relation of the active potash, the total potash, the acid-soluble potash, and the acid-insoluble potash to the crops grown on the soils in pot experiments, their potash content, and the amount of potash removed by the crops. The object is to ascertain more closely, if possible, the relation between the analysis of the soil and the ability of the soil to furnish potash for crops.

As shown in Bulletin 145, there is a close relation between the active potash of the soil and the potash taken up by crops. The active potash lost by cropping as shown by chemical analysis of the soil before and after cropping, is also closely related to the amount of potash removed by the crops, as shown in Bulletin 325. The bulletin here presented carries the study further, and other bulletins are in preparation relating to soil potash dissolved by other solvents.

HISTORICAL

Active potash and phosphoric acid were usually studied together.

Gerlach (1) concluded from several hundred experiments on dilute solvents for two years with 16 soils, that 1 per cent citric acid best served to indicate the needs of the soil for phosphoric acid. There were, however, exceptions.

Dyer (2) found the root acidity of 100 plants to vary from 0.34 with Solanaceae to 3.4 with Rosaceae and to average 0.91 per cent. He applied 1 per cent citric acid to soils of the Rothamsted Experiment Station and found the results with potash and phosphoric acid in accordance with the history and properties of the samples. He concludes that a soil containing less than .01 per cent potash or phosphoric acid soluble in this solvent is usually in need of a corresponding fertilizer.

The American Association of Official Agricultural Chemists (3), through various Referees, undertook studies of citric acid and other solvents. Nitric acid 0.2 N with correction for neutralization was adopted as official for several years, but was eliminated in revising the methods in 1917, a serious mistake in the opinion of the writer.

The Experiment Station at Halle (5), Germany, used weak citric acid.

Liebscher (6) obtained results in accordance with those of Dyer.

The Massachusetts Experiment Station (7) obtained results which did not correspond with the yield of crops.

Sap-acidity of wheat (8) was found to be equal to 0.48 per cent citric acid, while that of clover was 1.02 per cent. Hall and Plymen (9) tested 1 per cent citric acid, equivalent hydrochloric acid, acetic acid, and water saturated with carbon dioxide, on 19 soils. The 1 per cent citric acid gave results most nearly in agreement with the recorded history of the soil, though there is evidence that the same interpretation cannot be placed on results obtained from all types of soils.

Cousins and Hammond (10) found Dyer's method unsatisfactory on the highly calcareous soils of Jamaica, unless the acid was corrected for the lime present, and then the results agreed with the known productiveness.

Kudashey (11) recommends ½ per cent oxalic acid and reports results on 62 samples of soils.

The Dyer method agreed with field tests on clay soils but not with other types of soils (12).

Moore (4) compared the quantity of potash and phosphoric acid extracted from the soil by dilute acids, with the quantity removed by crops from the soil, regardless of the deficiencies of the soils for any particular plant food. On the basis of this work he proposed the use of .02 normal hydrochloric acid.

Buler (13) states that water containing carbon dioxide gives better results than dilute acids. He regards soil containing less than 0.015 per cent potash soluble in carbonated water as deficient.

Ingle (14) found in pot experiments that extraction with 1 per cent citric acid makes the soil less productive for crops at first, but the active plant food is gradually restored.

Fraps (15) found a close relation between the active potash of the soil and the potash taken up by crops. The active potash lost by cropping was also shown to be closely related to the potash removed by the crops.

SOIL POTASH AS RELATED TO THE PLANT

The amount of potash removed by the plant depends upon a number of factors. The kinds of potash compounds in the soil and the relative amounts, are both important, but are by no means the only factors. In pot experiments efforts are made to eliminate all other variables; yet this cannot be done completely.

The factors which affect the potash removed by plants in pot experiments include the quality and quantity of the different potash compounds in the soil, the kind of plant; conditions of growth, such as temperature, water supplied, and time of growth; the relation between the number of plants and the quantity of soil, and others. Both the chemical character and the physical character of the soil are also of effect. If the soil has a poor water capacity or assumes a poor physical condition, the growth of the plant will be retarded and the amount of potash taken up by the plant may be low. Plants may make a small growth, but at the same time take up a high percentage of potash; so analysis of the plant is always necessary.

Under field conditions more variables enter into play, making the connection between field growth and pot results quite difficult to correlate. Natural variations in the soil in the field are of considerable effect. The depth of the surface soil and the depth and character of the subsoil and seasonal conditions including temperature and moisture conditions, affect the amount of plant food absorbed. The ratio of plant growth to soil available is also of significance.

SOIL POTASH AS RELATED TO THE SOLVENT

The potash dissolved by solvents from the soil depends upon several groups of factors. The more important ones are as follows:

(1) The nature of the solvent, including the strength of solvent, the time of contact, the temperature, and ratio of soil to solvent. These are discussed to some extent in Bulletin 145.

(2) The relative abundance of the potash-bearing compounds in the soil. Absorbed potash, and minerals such as leucite or phillipsite give up 15 to 60 per cent of their potash to 1.2 nitric acid; biotite and glauconite less than 10 per cent; and microcline and orthoclase practically none, as shown in Texas Bulletin 145.

(3) The solubility of soil materials which protect or enclose potash minerals.

(4) The power of the soil to fix potash under the conditions of the experiment. This varies with the solvent used. As shown in Texas Bulletin 145, this factor is not of great importance with potash when 0.2N nitric acid is used.

METHOD OF WORK

The pot experiments were carried out as described in previous bulletins. The dry soil was passed through a sieve and 5000 grams placed in pots which had already had gravel placed in them. Dicalcium phosphate and ammonium nitrate were added to the no-potash pots. The pots were watered and corn or other seed planted. The pots were kept in a greenhouse and watered three times a week, or oftener if necessary. Two crops were grown in succession, corn being usually the first, sorghum or kafir the second. The crops were harvested, dried, weighed, and the potash determined in them.

The pots were kept in a greenhouse, and grown during the summer, when the temperature sometimes became quite high. It was realized that this high temperature would affect the results, but it could not be avoided. The results must be considered as comparative, not absolute, for under lower temperatures and other different conditions, different amounts of potash would have been taken up by the plants. The amount of potash taken up under more moderate temperatures would probably be lower. The conditions were kept similar as nearly as possible.

STATISTICAL METHODS

Statistical methods are used in genetics, economics, and other studies as an aid to unravel factors operating in complex conditions. These methods are applicable to soil studies and have been used in previous bulletins. The results secured will be discussed in connection with the subject matter.

METHODS OF ANALYSIS

The active potash was estimated by solution in 0.2N nitric acid, digesting 5 hours at 40°. No correction was made for the neutralization of the acid by the bases.

The total potash was estimated by the Lawrence-Smith Method.

The acid-soluble potash is that dissolved by 1.115 hydrochloric acid by the Hilgard method.

The acid-insoluble potash is the difference between the total potash and the acid-soluble potash.

The detailed methods are not available elsewhere and are given at the end of this Bulletin.

RELATION OF POTASH REMOVED BY CROPS TO SOIL ANALYSIS

The average results arranged according to the potash removed by two crops in 329 experiments are given in Table 1. In this table, if two or more pots of the same soil were used, the results were averaged before being used to prepare the table. As the potash removed by the crops increases, there is generally an increase in the active potash, the total potash, and the acid-soluble potash.

Until the potash removed by the crops exceeds 600 parts per million of the soil, the active potash increases regularly. After this there is a decrease in the active potash.

Until the potash removed by two crops exceeds 300 parts per million, both the total potash and the acid-soluble increase regularly, after which it is irregular with a tendency to increase.

These are discussed more fully below.

In interpreting the results of the chemical analysis of the soil, it is necessary to judge the possible crop production or deficiency from the analysis. For this reason, it was considered more important to arrange the results according to the analyses than according to the crops, though such arrangements involve more work and more tables.

Table 1.—Soils arranged according to potash removed by two crops, averaged if more than one pot of the same soil

Potash Removed by Two Crops—Per Million of Soil	Potash in 2 Crops p. m.	Average Per Crop p. m.	Active Potash p. m.	Total Potash Per Cent	Acid Soluble Potash Per Cent	Number Averaged
0– 50.............	42	21	66	.43	.07	14
51–100.............	77	39	85	.59	.11	57
101–150.............	122	62	128	.79	.23	55
151–200.............	173	87	164	.99	.29	45
201–250.............	226	113	244	1.17	.46	35
251–300.............	270	135	306	1.53	.65	15
301–400.............	347	174	349	1.43	.63	30
401–500.............	433	217	352	1.30	.61	14
501–600.............	539	270	801	1.89	.93	7
Over 600............	665	333	628	1.79	1.14	

RELATION OF ACTIVE POTASH TO POTASH REMOVED BY CROPPING

The average results of the experiments arranged according to the active potash of the soil are given in Table 2. Each pot is included separately though there are sometimes more than one pot of the same

Table 2.—Averages of soils arranged by active potash.

No. Averaged	Active Potash Per Mil.	Weight First Crop gm.	Weight Second Crop gm.	Potash in 1st Crop p. m.	Potash in 2nd Crop p. m.	Potash Two Crops p. m.	Active Potash Soil p. m.	Potash in 1st Crop p. m.	Potash in 2nd Crop p. m.
6	25– 50	26.4	17.1	43.3	17.8	61.2	40	.83	.53
27	50– 75	28.6	21.7	47.1	29.6	76.7	62	1.09	.75
46	75–100	32.0	21.4	69.4	32.5	99.7	88	1.23	.84
41	100–125	38.7	20.0	85.6	35.4	120.2	110	1.66	.93
30	125–150	33.1	22.1	101.6	48.6	149.5	136	1.74	1.13
37	150–175	32.2	20.9	110.0	44.7	153.7	163	1.74	1.22
16	175–200	36.3	27.4	139.1	61.6	194.5	189	2.05	1.12
16	200–225	34.9	26.8	171.5	56.8	226.0	211	2.65	1.22
15	225–250	32.7	27.3	190.9	88.1	273.0	241	3.11	1.76
19	250–275	33.1	25.5	201.6	81.1	280.9	259	3.41	1.74
10	275–300	30.1	26.2	171.9	118.4	257.6	288	3.02	2.24
6	300–325	31.8	33.0	243.0	112.6	338.5	317	3.74	1.80
7	325–350	30.0	26.1	234.5	90.4	325.0	338	3.97	1.87
5	350–375	26.1	22.9	231.2	88.0	319.2	364	4.69	2.31
6	375–400	30.0	29.5	209.7	98.6	332.3	390	3.62	2.00
4	400–425	37.9	36.7	254.0	100.0	354.0	405	3.33	1.36
2	425–450	32.7	22.8	288.0	74.0	362.0	438	4.42	1.78
3	450–475	32.4	26.3	259.0	98.0	357.0	463	4.44	1.93
2	475–500	28.7	11.2	229.0	67.0	244.0	488	4.23	2.97
1	500–525	40.1	26.0	379.0	72.0	451.0	524	4.73	1.38
4	525–550	36.0	30.5	293.0	151.0	444.0	535	4.20	2.43
4	550–575	26.9	42.2	248.0	166.0	414.0	568	4.78	2.12
1	600–625	41.1	....	193.0	....	201.0	601	....	....
1	625–650	46.8	34.9	491.0	174.0	665.0	628	5.52	2.50
1	725–750	34.8	....	338.0	....	450.0	736	....	....
1	775–800	23.2	29.6	199.0	132.0	331.0	791	4.28	2.24
4	1000-1409	30.8	31.1	383.0	180.0	563.0	1207	6.23	2.90

soil. The number of samples in the groups exceeding 575 parts active potash per million is not satisfactory for proper averages, but there also are some groups below which do not contain enough samples.

Weight of crop. While the average weight of the crop is a little lower at first, no regular relation can be traced between these weights and the active potash of the soil. The correlation coefficient, r, for the weight of the first crop and the active potash is $+ .045 \pm .055$, or practically none at all. These facts indicate that the weight of the crop alone cannot be correctly used to study the potash of the soil.

Per cent potash in crop. The average percentage of potash in the crop increases with the active potash in the soil. This applies both to the first and the second crop. The percentage of potash in the second crop is less than in the first, decidedly so in many cases. Usually the first crop was corn, the second sorghum, both grown the same year. The difference may be in part due to the nature of the crop, in part to the fact that the first crop has removed some of the active potash.

The average percentages of potash in the first crop (corn), range from 0.87 to 6.23 per cent, and in the second crop (sorghum), from 0.52 to 2.97 per cent. These results show that estimates of the availability of potash minerals or of soil potash based upon weights of the crop alone are open to serious question, to say the least.

The correlation coefficient, r, for the percentage of potash in the first crop and the active potash in the soil is $+ .194 \pm .053$. This is a low correlation.

Potash taken up by the crop. The amount of potash taken up by the crop, expressed in parts per million of the soil, is given for the first crop, the second crop, and for the two combined. There is a close relation between the active potash in the soil and the amount of potash taken from the soil by crops. While the active potash is not the only factor involved, it is certainly an important one.

The potash taken up by the first crop is larger than that taken up by the second. It is believed that the potash taken up by the two crops represents the ability of the soil to give up potash a little better than either the first crop or the second crop alone.

Statistical Relations

The correlation coefficient for the active potash in the soil and the potash taken up by the first crop is $+ .742 \pm .019$. The correlation coefficient for the active potash and the potash taken up by two crops is $0.794 \pm .014$. In both cases the correlation is high, but the two crops give a better correlation than the first crop. It is believed that this is due to the tendency of the second crop to equalize variations in the first crop due to seasonal or other conditions.

Calculation of the Relation of the Active Potash to the Potash Removed by the Crops

The question of the degree of accuracy with which it is possible to estimate the potash removed by crops in pot experiments from the active potash is a matter of considerable importance. The relation of the potash taken up by crops to potash in the soil under field conditions is also of great importance, but is a more difficult problem and is not discussed here.

It must be remembered that the amount of potash removed by crops in pot experiments is not an absolute measure of the availability of the potash in the soil, since the growth of the crops is affected by other factors than the quantity of available potash. It is the best measure we have at the present time, however.

The relations between the average amounts of potash removed by the crops and the active potash in the soil are shown graphically in Figures 1 and 2. The averages are grouped in both curves quite regularly up to about 450 parts per million of active potash, beyond which the points are more scattering. The number of samples of soils containing more than 450 parts per million were in many of the groups insufficient for fair averages, and this fact prevents the formation of a correct opinion

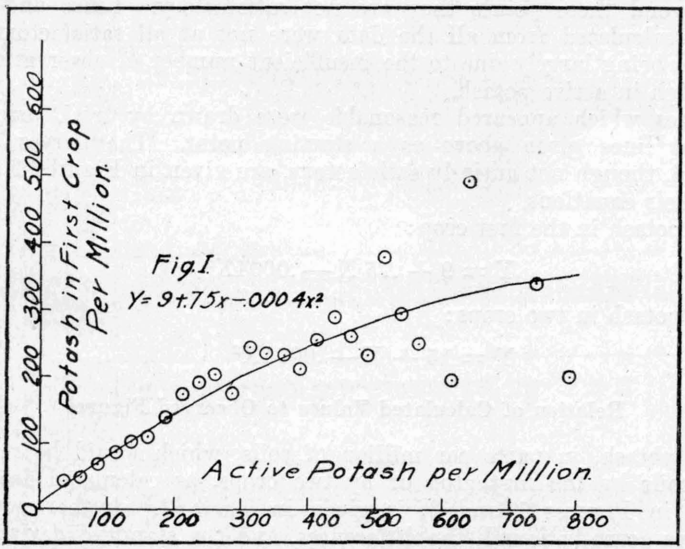

Figure 1.—Relation of the active potash of the soil to potash removed by the first crop, with approximate curve.

of the relation between the active potash of the soil and the potash removed by crops for soils containing high amounts of active potash.

Straight lines calculated for the two figures up to 325 parts per million active soil potash by means of the method of least squares are as follows:—

(1) For the first crop:

Potash removed by the first crop = 9 + .70 active potash in the soil

or:

$$y = 9 + .70\,X$$

(2) For the two crops:

Potash removed by two crops = 15 + .967 times the active potash of the soil

or:

$$Y = 15 + .976\,X$$

These lines are in close agreement up to 250 parts per million of active potash for the first crop, and 350 parts per million for two crops, but beyond these points they are not satisfactory. Lines and other curves calculated from all the data were not at all satisfactory, this perhaps being largely due to the insufficient number of observations on soils high in active potash.

Curves which appeared reasonable were drawn by trial, using the straight lines given above as a starting point. The curves finally adopted, though not entirely satisfactory, are given in Figures 1 and 2, with their equations.

For potash in the first crop:

$$Y = 9 + .75\,X - .0004X^2$$

For potash in two crops:

$$Y = 15 + X - .0004X^2$$

Relation of Calculated Values to Observed Figures

The potash, in parts per million of soils, which would be removed from soils by the first crop or by two crops, as calculated from the curves in Figures 1 and 2, is given in Table 3, together with the averages actually found, the differences, and the standard deviation of the individual actual values from the calculated value in each group in which three or more soils were used. The values calculated and found agree very well.

The percentile deviation is also given. This is the standard deviation divided by the calculated value, expressed in percentages.

Table 3.—Relation of the potash taken up by crops as calculated from active potash, according to the equations, to the average found in pot tests. Parts per million of soil.

Number of Soils	Groups (Active Potash)	In the First Crop					In Two Crops				
		Found	Calculated	Difference	Standard Deviation	Percentile Deviation	Found	Calculated	Difference	Standard Deviation	Percentile Deviation
6	25– 50	43	37	—6	15	41	61	52	—9	22	42
27	50– 75	47	55	8	18	33	77	76	—1	34	45
46	75–100	69	73	4	24	33	100	99	—1	35	35
41	100–125	86	88	2	24	27	120	122	2	35	29
30	125–150	102	105	3	27	26	150	145	—5	37	26
37	150–175	110	121	11	28	23	154	167	3	40	24
16	175–200	139	137	—2	25	18	195	187	—7	53	28
16	200–225	172	150	—22	78	52	226	209	—17	68	33
15	225–250	191	165	—26	59	36	273	230	—43	92	40
19	250–275	202	179	—23	68	38	281	250	—31	97	39
10	275–300	172	193	21	55	28	258	269	11	96	36
6	300–325	243	204	—39	60	29	339	288	—51	77	27
7	325–350	235	217	—18	63	29	325	307	—18	59	19
5	350–375	231	229	—2	10	4	319	325	6	71	22
6	375–400	210	239	—29	38	16	332	342	10	37	11
4	400–425	254	250	—4	7	3	354	359	5	54	15
2	425–450	288	261	—27	.....	.....	362	376	14	.....	.....
3	450–475	259	271	12	55	20	357	392	35	.....	.....
2	475–500	229	281	52	.....	.....	244	407	—163	.....	.....
1	500–525	379	288	91	.....	.....	451	422	—29	.....	.....
4	525–550	293	297	4	22	7	444	437	—7	.....	.....
4	550–575	248	305	57	127	42	414	451	37	72	16
0	575–600	.....	313	.....	.....	.....	.....	464	.....	.....	.....
1	600–625	193	318	125	.....	.....	201	477	276	.....	.....
1	625–650	491	325	—166	.....	.....	665	490	—175	.....	.....
.....	650–675	.....	331	.....	.....	.....	.....	502	.....	.....	.....
.....	675–700	.....	337	.....	.....	.....	.....	613	.....	.....	.....
.....	700–725	.....	341	.....	.....	.....	.....	524	.....	.....	.....
1	725–750	338	346	8	.....	.....	450	535	85	.....	.....
.....	750–775	.....	349	.....	.....	.....	.....	545	.....	.....	.....
1	775–800	199	353	154	.....	.....	331	554	223	.....	.....
.....	800–825	.....	355	.....	.....	.....	.....	563	.....	.....	.....
.....	825–850	.....	357	.....	.....	.....	.....	572	.....	.....	.....
.....	850–875	.....	359	.....	.....	.....	.....	580	.....	.....	.....
.....	875–900	.....	360	.....	.....	.....	.....	588	.....	.....	.....
.....	900–925	.....	360	.....	.....	.....	.....	594	.....	.....	.....
.....	925–950	.....	361	.....	.....	.....	.....	601	.....	.....	.....
.....	950–975	.....	361	.....	.....	.....	.....	607	.....	.....	.....
.....	975–1000	.....	361	.....	.....	.....	.....	612	.....	.....	.....
4	1000–1409	383	361	22	.....	.....	563	612	—49	.....	.....
Average	.....	.....	.....	.....	.....	27	.....	.....	.....	.....	29

The standard deviation which is expressed in parts per million is irregular but tends to increase as the active potash increases. The percentile deviation is somewhat higher with the soils containing the smallest amounts of active potash.

The average percentile deviation is about 30 per cent. This multiplied by .67 gives about 20 per cent, which means that it is approximately an even chance there will be an average variation of 20 per cent, according to statistical theory.

RELATION OF ACID-SOLUBLE POTASH TO THE CROP

The results of the experiments arranged by the acid-soluble potash of the soil are given in Table 4. The weights of the first crops are irregular, but a slight increase in weight of the second crop is found in the first part of the table. As the acid-soluble potash increases, there is an increase in the potash removed by both the first and the second crops, and by the two crops combined. There is also an increase in the active potash and in the total potash, showing that the quantity of these is related to the acid-soluble potash.

The correlation coefficient between the acid-soluble potash of the soil and the potash removed by two crops is $+.667 \pm .013$. This is a high correlation, but not as high as $+.794 \pm .014$ found for the active potash and the potash removed by two crops.

The correlation coefficient between the acid-soluble potash and the active potash is $+.761 \pm .019$, or closer than for the acid-soluble potash and the potash removed by the crops. While the amount of acid-soluble potash in the soil is related to the potash removed by the crops, it is probable that this is due largely to the fact that an increase in acid-soluble potash is accompanied by an increase in active potash, and is thus largely to be ascribed to the active potash.

The averages for the acid-soluble potash are plotted in Figures 3 and 4. The points seem to be arranged in two parallel lines up to about 0.6 per cent acid-soluble potash, after which they become scattering.

No satisfactory curves were calculated from the data. Straight lines were plotted from observation up to 0.6 per cent acid-soluble potash, after which the writer assumes there is no further increase. The lines plotted are:

(3) Potash removed by first crop = 60 + 270 times acid-soluble potash (up to 0.6 per cent)

or

$$Y = 60 + 270X$$

(4) Potash removed by two crops = 83 + 392 times acid-soluble potash up to 0.6 per cent

or

$$Y = 83 + 392X$$

Table 4.—Average of soils arranged according to their content of acid-soluble potash.

Acid Soluble Potash, Per Cent	Weight First Crop, gm.	Weight Second Crop, gm.	Potash in First Crop, p. m.	Potash in Second Crop, p. m.	Potash in Two Crops, p. m.	Active Potash, p. m.	Per Cent Potash in First Crop	Per Cent Potash in Second Crop	Total Potash Per Cent in Soil	Acid Soluble Potash in Soil	Number Averaged
0–0.06	35.9	18.4	59.1	22.8	81.9	92.5	0.83	0.69	0.58	0.04	40
.061– .120	35.4	21.2	83.4	34.5	117.9	122.4	1.19	0.89	0.65	0.09	48
.121– .180	38.7	25.5	124.2	41.1	165.3	153.6	1.67	0.89	0.68	0.15	26
.181– .240	34.1	24.7	103.6	35.4	139.0	122.5	1.64	0.71	0.77	0.21	24
.241– .300	30.8	20.4	155.0	72.9	219.5	249.8	2.65	1.78	0.84	0.26	23
.301– .360	30.2	20.2	139.2	49.2	190.3	188.0	2.26	1.29	0.81	0.33	17
.361– .420	31.7	23.9	184.4	76.6	254.8	278.0	2.77	1.54	1.09	0.38	16
.421– .480	29.4	26.1	156.9	76.6	233.5	211.9	2.85	1.58	1.09	0.46	12
.481– .540	33.1	29.4	209.2	108.2	317.4	316.6	3.32	1.84	1.35	0.51	9
.541– .600	32.9	31.7	231.9	96.6	328.5	295.6	3.77	1.55	1.49	0.56	14
.601– .660	32.6	21.4	214.0	89.4	303.4	397.0	3.06	1.74	1.43	0.64	5
.661– .720	35.2	29.1	228.5	103.2	331.7	335.8	30.50	1.93	1.78	0.07	10
.721– .780	20.4	28.9	180.0	96.0	276.0	333.0	4.54	1.65	1.32	0.76	2
.781– .840	40.2	20.5	329.7	70.7	400.3	723.3	5.04	1.81	1.42	0.82	3
.841– .900	29.4	13.9	205.0	35.3	240.3	300.3	3.44	1.87	2.28	0.88	3
.901– .960	13.5	40.2	144.0	160.0	304.0	561.0	5.34	1.99	2.43	0.96	1
.961–1.020	19.0	15.8	180.7	89.3	270.0	298.7	3.51	2.28	2.15	0.99	3
1.021–1.080	10.9	6.9	123.0	39.0	162.0	256.0	5.68	2.85	2.26	1.07	2
1.081–1.140	19.3	1.5	225.5	10.5	236.0	367.0	5.85	2.50	2.39	1.11	2
1.141–1.200	33.7	33.6	266.5	148.0	414.5	616.5	3.89	2.25	2.22	1.18	4
1.132–1.380	36.8	31.5	334.5	171.0	505.5	905.5	4.77	2.75	2.52	1.34	4
1.381–1.440	24.3	29.6	262.0	149.0	410.5	642.5	5.19	2.49	1.91	1.43	4
1.501–1.560	20.8	11.2	211.0	67.0	278.0	485.0	5.09	2.97	2.71	1.55	1

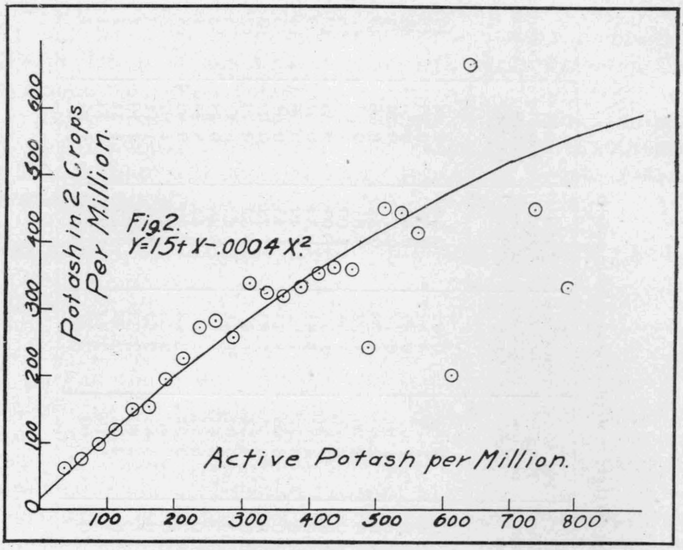

Figure 2.—Relation of the active potash in the soil to the potash removed from the soil by two crops, with approximate curve.

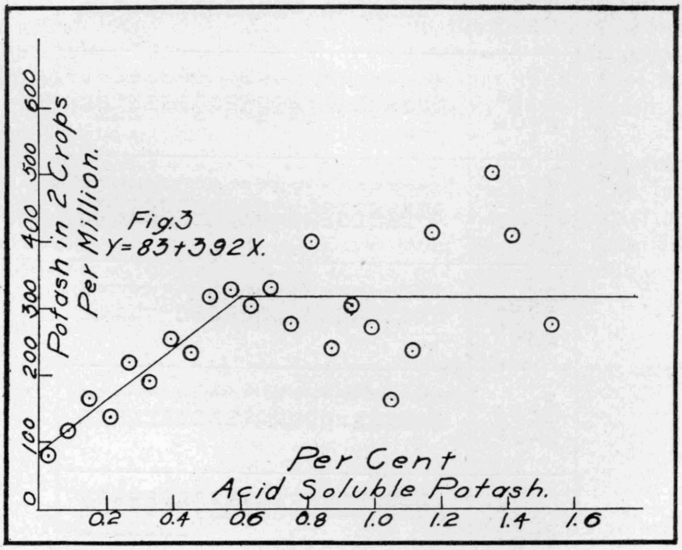

Figure 3.—Relation of the acid-soluble potash in the soil to the potash taken up by two crops, with approximate curve.

RELATION OF OBSERVED TO CALCULATED VALUES FOR ACID-SOLUBLE POTASH

The relations between the potash removed from the soil by the first crop and by two crops, to the values calculated from the acid-soluble potash by the formulas just given, are shown in Table 5.

The difference is that between the observed and calculated values. The standard deviation represents the variations of the results of the individual pot experiments from the calculated values for each group. The percentile deviation is the standard deviation divided by the calculated results, expressed as per cent. The average percentile deviation is 44 and 38, which is greater than about 30 per cent found for active potash.

Examination of the table shows that prediction by means of acid-soluble potash is much less close than by means of active potash. This is confirmed by observation of Figures 3 and 4, and by the lower correlation between the acid-soluble potash and the potash removed by crops.

RELATION OF TOTAL POTASH TO CROP

The results arranged according to the total potash of the soil are given in Table 6. The weights of the crops are irregular. The potash withdrawn from the soil by the first crop, by the second and by the two crops combined, increases with the total potash of the soil. There is evidently a relation between the total potash of the soil and the potash removed by the crops. The active potash and the acid-soluble potash also increase as the total potash increases, showing that these three kinds of potash are related to one another.

Table 5.—Relation of the potash taken up by crops as calculated from the acid-soluble potash to the average found in pot tests. Parts per million of soils.

No. of Soils	Groups (Acid-Soluble Potash)	In the First Crop					In Two Crops				
		Found	Calculated	Difference	Standard Deviation	Percentile Deviation	Found	Calculated	Difference	Standard Deviation	Percentile Deviation
40	0–0.06......	59	68	9	28	41	82	95	13	33	35
48	.061– .120.....	83	84	1	41	49	118	118	0	63	53
26	.121– .180.....	124	101	—23	76	75	165	142	—23	78	55
24	.181– .240.....	104	117	13	40	34	139	165	26	56	34
23	.241– .300.....	155	133	—22	87	65	220	189	—31	132	70
17	.301– .360.....	139	149	10	63	42	190	212	22	80	38
16	.361– .420.....	184	165	—19	67	41	255	236	—19	82	35
12	.421– .480.....	157	182	25	82	45	234	259	26	118	46
9	.481– .540.....	209	198	—11	206	104	317	283	—34	118	42
14	.541– .600.....	232	214	—18	81	38	329	306	—23	111	36
5	.601– .660.....	214	230	16	83	36	303	330	27	93	28
10	.661– .720.....	229	230	2	91	40	332	330	—2	118	36
2	.721– .780.....	180	230	50	51	22	276	330	54	65	20
3	.781– .840.....	330	230	—100	140	61	400	330	—70	163	49
3	.841– .900.....	205	230	25	68	30	240	330	—10	53	16
1	.901– .960.....	144	230	86	86	37	304	330	26	26	8
3	.961–1.020.....	181	230	49	68	30	270	330	60	65	20
2	1.021–1.080.....	123	230	107	107	47	162	330	168	168	51
2	1.081–1.140.....	226	230	5	7	3	236	330	94	94	28
4	1.141–1.200.....	267	230	—37	87	38	415	330	—85	137	42
4	1.321–1.380.....	335	230	—105	131	57	506	330	—176	190	58
4	1.381–1.440.....	262	230	—32	163	71	411	330	—81	176	53
1	1.501–1.560.....	211	230	19	19	8	278	330	52	52	16
	Average (23)...	....	....	....	....	44	....	....	....	....	38

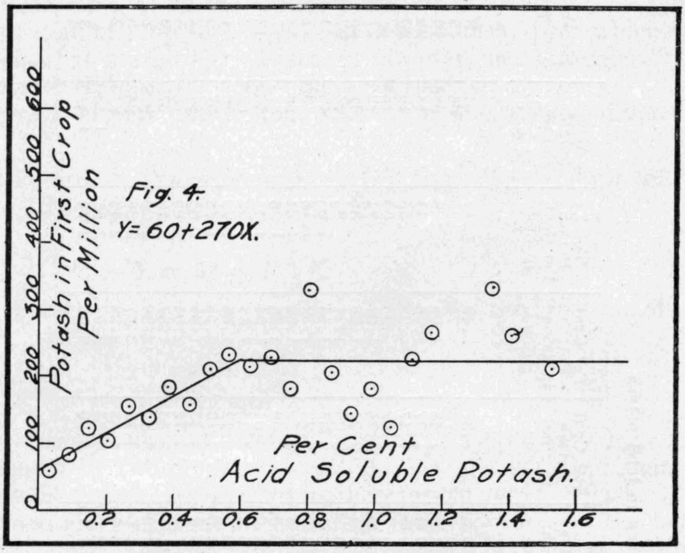

Figure 4. Relation of the acid-soluble potash in the soil to the potash taken up by the first crop, with approximate curve.

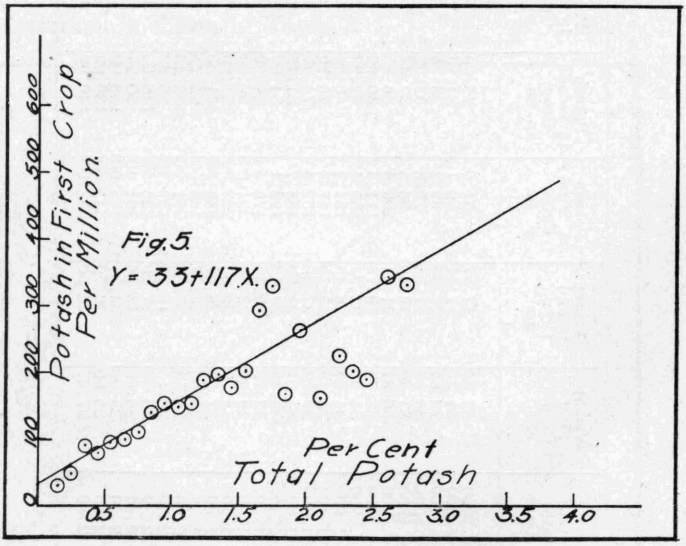

Figure 5.—Relation of total potash of the soil to potash removed by the first crop, with approximate curve.

Table 6.—Soils averaged according to total potash

Total Potash, Per Cent	Weight First Crop, gm.	Weight Second Crop, gm.	Potash in First Crop, p. m.	Potash in Second Crop, p. m.	Potash in Two Crops, p. m.	Active Potash, p. m.	Per Cent Potash in First Crop	Per Cent Potash in Second Crop	Total Potash Per Cent, in Soil	Acid-Soluble Potash, Per Cent, in Soil	Number Averaged
.101- .200	32.43	17.57	31.0	17.00	48.0	50.33	.873	.49	.17	.043	3
.201- .300	34.27	17.41	50.1	21.93	72.0	82.33	.766	.766	.253	.06	15
.301- .400	29.64	21.34	89.2	28.85	118.1	114.35	1.48	1.05	.36	.088	14
.401- .500	30.56	21.28	79.8	33.58	112.92	99.04	1.37	.98	.44	.144	25
.501- .600	33.30	18.56	96.5	37.47	134.0	129.90	1.47	.956	.55	.19	30
.601- .700	36.81	21.04	100.6	36.85	132.0	125.73	1.52	.946	.65	.164	27
.701- .800	33.73	19.78	111.3	40.62	150.44	165.92	1.75	1.07	.74	.22	27
.801- .900	34.36	22.74	139.4	62.92	202.28	216.44	2.24	1.66	.853	.31	25
.901-1.00	34.64	26.43	151.2	60.00	213.85	206.30	2.23	1.21	.95	.26	27
1.00 1.10	28.10	25.10	147.6	75.90	223.5	246.60	2.83	1.44	1.05	.45	24
1.10 -1.20	29.52	27.96	152.4	74.47	226.8	213.00	2.72	1.32	1.16	.335	17
1.21 -1.30	33.51	21.03	188.7	61.42	259.25	262.4	2.59	1.62	1.24	.53	12
1.31 -1.40	34.48	27.13	196.1	84.00	291.82	270.00	3.06	1.68	1.36	.37	17
1.41 -1.50	32.12	30.15	175.5	86.50	262.08	248.90	3.01	1.34	1.46	.302	12
1.51- 1.60	29.40	23.30	201.0	90.00	291.00	280.50	4.25	1.89	1.52	.623	2
1.61 -1.70	43.70	29.80	293.00	102.00	395.00	530.00	3.12	1.68	1.70	.70	1
1.71 -1.80	37.90	28.27	330.30	141.30	470.70	658.00	4.10	2.55	1.78	.67	3
1.81- 1.90	25.83	28.77	166.50	96.75	263.25	289.25	3.33	1.85	1.85	.847	12
1.91- 2.00	26.54	36.56	261.20	152.40	413.60	567.20	4.72	2.06	1.95	.784	5
2.01- 2.20	26.13	16.27	159.70	56.80	221.00	244.70	3.43	1.87	2.10	.673	9
2.21- 2.30	28.56	27.00	226.50	118.00	344.50	364.00	4.14	2.36	2.26	.970	8
2.31- 2.40	26.88	13.26	201.40	50.25	251.6	314.00	4.12	2.37	2.36	.942	5
2.41- 2.50	25.05	34.2	195.00	158.00	353.00	526.00	4.35	2.38	2.43	.815	2
2.61- 2.70	36.00	30.70	341.50	180.00	521.50	832.00	4.73	2.92	2.61	1.180	2
2.71- 2.80	27.67	22.50	332.00	140.00	472.00	1101.10	5.90	3.09	2.74	1.410	3

Figures 5 and 6 show the relation between the total potash of the soil and the potash removed by the first crop and by two crops. The points are grouped regularly up to 1.5 per cent total potash, after which they become somewhat scattering. There is, however, more regularity for the total potash than for the acid-soluble potash.

The curves used were drawn from observation and their equations are as follows:

(5) Potash in first crop = 33 + 117 times total potash of the soil

or

$$Y = 33 + 117\,X$$

(6) Potash in two crops = 22 + 174 times total potash of the soil

or

$$Y = 22 + 174\,X$$

The correlation coefficient between the total potash of the soil and the potash removed by two crops is $+.662 \pm .023$. This is less than for the acid-soluble potash, and much less than for the active potash.

The correlation coefficient between the total potash and the active potash is $+.630 \pm .038$, and for the total potash and the acid-soluble potash $+.792 \pm .020$. It is again a question whether the relation of the total potash to the potash removed is due to the total potash itself, or to the relation between the total and the active potash.

The relation of the calculated to the observed figures, with the standard deviation, is shown in Table 7.

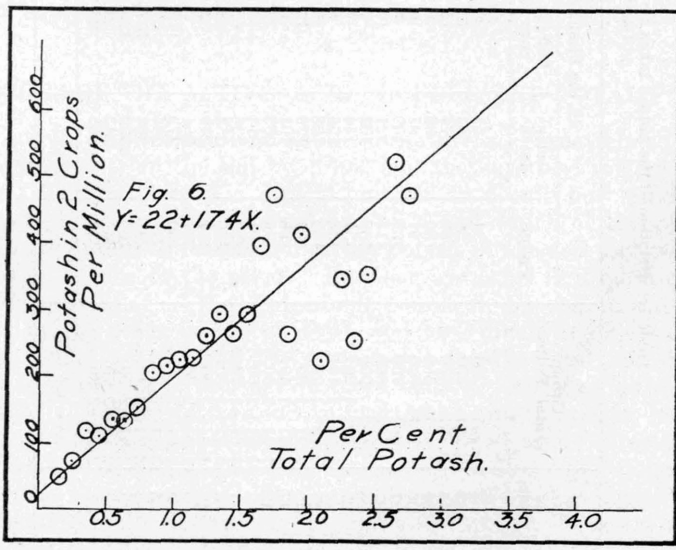

Figure 6.—Relation of the total potash in the soil to the potash taken up by two crops, with approximate curve.

Table 7.—Relation of the potash taken up by crops as calculated from total potash to the averages found in pot tests in parts per million of soil.

No. of Soils	Group (Total Potash)	In the First Crop					In Two Crops				
		Found	Calculated	Difference	Standard Deviation	Percentile Deviation	Found	Calculated	Difference	Standard Deviation	Percentile Deviation
3	.101– .200.....	31	51	20	20	39	48	48	0	6	13
15	.201– .300.....	50	62	12	24	39	72	66	—6	28	42
14	.301– .400.....	89	74	—15	96	130	118	83	—35	104	125
25	.401– .500.....	80	86	6	39	45	113	100	—13	53	53
30	.501– .600.....	97	97	0	38	39	134	118	—16	53	45
27	.601– .700.....	101	109	8	66	61	132	135	3	73	54
27	.701– .800.....	111	121	10	48	40	150	153	3	69	45
25	.801– .900.....	139	132	—7	72	55	202	169	—33	125	74
27	.901–1.00......	151	144	—7	73	51	214	187	—27	93	50
24	1.00 –1.10......	148	156	8	68	44	224	205	—19	100	49
17	1.10 –1.20......	152	168	16	78	46	227	222	—5	110	50
12	1.21 –1.30......	189	179	10	97	54	259	239	—20	124	52
17	1.31 –1.40......	196	191	—5	84	44	292	257	—35	117	46
12	1.41 –1.50......	176	203	27	110	54	262	274	12	157	57
2	1.51 –1.60......	201	214	13	....	....	291	292	1	....	....
1	1.61 –1.70......	293	226	—67	....	....	395	309	—86	....	....
3	1.71 –1.80......	330	238	—92	18	8	471	327	—144	246	75
12	1.81– 1.90......	167	249	83	100	40	263	344	81	109	32
5	1.91– 2.00......	261	261	0	103	39	414	361	—53	156	43
9	2.01 –2.20......	160	279	119	139	50	221	389	168	177	46
8	2.21– 2.30......	227	296	69	112	38	344	414	70	140	34
5	2.31– 2.40......	201	308	107	112	36	252	431	179	190	44
2	2.41 –2.50......	195	320	125	....	....	353	448	95	....	....
2	2.61 –2.70......	341	343	2	....	....	521	483	—38	....	....
3	2.71 –2.80......	332	355	23	88	25	427	501	74	156	31
	Average (25)...	....	....	....	....	45	....	....	....	....	48

The differences given are between the values calculated and those found. The standard deviation represents the variation of individual pot tests from the calculated values for each group, while the percentile deviation represents the same variation expressed in percentage of the calculated values.

The average percentile variation is larger in the prediction from the total potash than that for the active potash, being about 45 per cent, as compared with about 30 per cent in the prediction from the active potash.

RELATION OF ACID-INSOLUBLE POTASH TO THE CROP

The acid-insoluble potash is the term applied to the quantity left when the amount of acid-soluble potash is subtracted from the total potash. The results arranged according to the acid-insoluble potash are given in Table 8.

The results are more irregular than in the other tables, though there appears to be some tendency for the potash removed to increase as the acid-insoluble potash increases. The same tendency can be noted with the active potash, the total potash, and the acid-soluble potash.

The correlation coefficient between acid-insoluble potash and potash removed by two crops is $+.388 \pm .052$. For acid-insoluble potash and active potash it is $+.428 \pm .034$. These coefficients are much lower than those previously secured. This indicates that the acid-insoluble potash is much less significant, in relation to crops, than the acid-soluble potash. It also indicates that the acid-soluble is more important than the total potash.

On account of the small degree of correlation, no attempt was made to draw curves to show the relation of the acid-insoluble potash to the crops.

RELATIONS OF THE ACTIVE, ACID-SOLUBLE AND TOTAL POTASH

The active, acid-soluble, and total potash are all three related to the potash removed from the soil by crops, and they are also related to one another. This renders it a difficult matter to decide how much each contributes to the potash removed by crops, and which of the relations observed are due to the condition of the potash in the soil and which to the relation of one to the other. In other words, it is a question how much of the relation of the acid-soluble potash in the soil to the potash removed by the crops is due to itself, and how much to its association with the active potash, and the same holds for the total potash. An attempt has been made to separate these factors. For this purpose the relation of the three factors is assumed to be linear and to be as in Figure 7. The quantity of total potash is assumed to act directly upon the potash in the crops, and also through the acid-soluble potash and through the active potash. The amount of acid-soluble potash is assumed to act directly upon the crops, and also through the active potash. The amount of active potash is assumed to act directly. Other factors

Table 8.—Soil arranged by acid-insoluble potash

Acid Insoluble Potash Per Cent	Weight First Crop, gm.	Weight Second Crop, gm.	Potash in First Crop, p. m.	Potash in Second Crop, p. m.	Potash in Two Crops, p. m.	Active Potash, p. m.	Per Cent Potash First Crop	Per Cent Potash Second Crop	Per Cent Total Potash in Soil	Per Cent Acid Soluble in Soil Potash	Per Cent Acid Insol. in Soil	Number Averaged
0– .06	42.7	43.0	186.0	22.0	208.0	252.0	2.18	....	.42	.41	.01	1
.061– .120	28.4	12.9	34.7	18.3	53.0	81.3	2.16	1.07	.31	.19	.11	3
.121– .180	32.1	16.2	98.6	22.3	120.2	96.4	1.61	.69	.25	.09	.16	9
.181– .240	31.9	18.7	79.1	26.5	110.3	116.8	1.23	.86	.35	.13	.22	16
.241– .300	29.1	19.1	99.6	34.2	137.7	138.2	1.62	.90	.52	.24	.27	18
.301– .360	31.7	22.9	85.1	36.9	119.1	117.3	1.43	.78	.49	.16	.34	12
.361– .420	32.5	19.7	109.9	40.5	150.2	168.9	1.64	1.11	.59	.20	.39	22
.421– .480	36.0	21.7	127.7	44.1	167.5	177.0	2.01	1.12	.84	.38	.46	24
.481– .540	34.6	25.0	163.5	64.0	227.9	273.3	2.59	1.34	.91	.39	.53	23
.541– .600	31.5	25.7	150.4	74.4	223.4	238.2	2.48	1.34	.82	.25	.58	19
.601– .660	36.3	27.8	149.2	62.6	211.8	219.0	2.11	1.12	1.01	.37	.64	15
.661– .720	38.0	35.8	187.3	88.1	279.5	261.5	2.60	1.24	1.02	.33	.69	10
.721– .780	33.9	23.2	128.5	64.3	192.9	173.2	2.11	1.34	1.03	.31	.72	15
.781– .840	32.9	28.3	153.0	80.8	230.1	232.5	2.49	1.36	1.09	.27	.82	14
.841– .900	40.5	27.3	155.1	54.0	220.3	214.1	2.14	1.09	1.17	.31	.86	7
.901– .960	38.2	25.1	229.5	97.5	327.0	384.5	3.29	1.67	1.64	.71	.89	6
.961–1.020	36.9	18.2	175.4	67.2	241.6	284.0	2.26	1.37	1.31	.33	.98	7
1.021–1.080	35.5	23.9	143.2	49.7	204.4	236.0	1.95	1.17	1.40	.35	1.05	5
1.081–1.140	30.5	16.9	68.0	44.5	112.5	112.0	1.08	1.79	1.50	.37	1.13	2
1.141–1.200	18.1	8.1	175.2	43.0	218.2	335.7	5.14	2.61	2.35	1.17	1.18	4
1.201–1.260	31.1	29.1	130.9	82.0	213.0	217.3	1.89	1.55	1.70	.47	1.23	7
1.261–1.320	32.2	12.6	19.8	31.0	228.8	302.6	3.80	2.01	1.94	.66	1.28	5
1.321–1.380	37.4	15.9	71.5	20.0	91.5	122.0	.98	.69	1.41	.06	1.35	2
1.381–1.440	33.3	30.0	259.9	137.9	397.8	681.0	4.07	2.18	2.19	.78	1.42	8
1.441–1.500	23.3	25.7	155.0	82.3	237.3	340.3	3.68	1.82	2.38	.92	1.46	3
1.501–1.560	39.7	26.0	222.3	87.7	310.0	261.0	2.74	1.69	2.06	.51	1.54	6
1.561–1.620	39.4	26.5	235.0	....	378.0	376.0	3.21	....	2.31	.69	1.62	1
1.621–1.900	28.5	25.3	180.2	100.5	269.8	399.8	3.20	1.77	2.14	.53	1.61	5

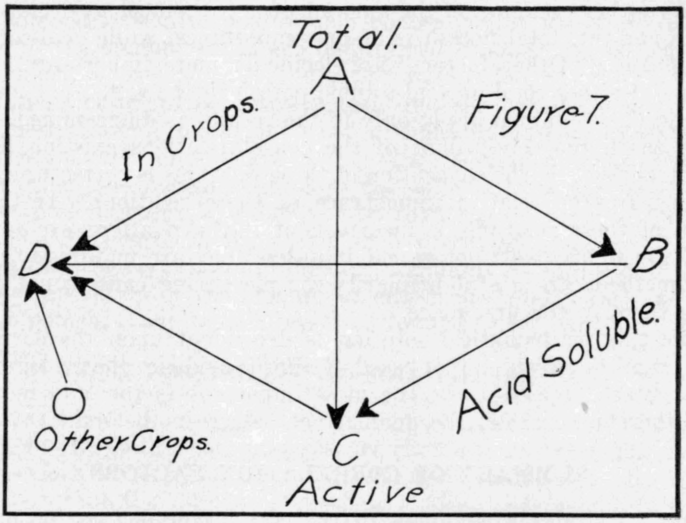

Figure 7.—Assumed relations of the quantity of potash in the soil in different forms to the quantity taken up by crops.

besides the amounts of these kinds of potash in the soil influence the amounts in the crop, and these factors are represented by 0.

The following solution was kindly furnished by Dr. J. L. Lush, Animal Husbandman. (16)

$$r(AB) = d = .79$$
$$r(AC) = f + e.r(AB) = .63$$
$$r(BC) = e + f.r(AB) = .76$$
$$r(AD) = a + b.r(AB) + fc + ec.r(AB) = .62$$
$$r(BD) = a.r(AB) + b + ec + fc.r(AB) = .67$$
$$r(CD) = fa + ea.r(AB) + eb + fb.r(AB) + c = .79$$
$$O = \sqrt{1 - r^2(D.ABC)}$$

The values secured from the above calculations are as follows:

a (total potash)	= .189
b (acid-soluble potash)	= .013
c (active potash)	= .669
O (other factors)	= .520

If the assumption is changed to have the active potash and the acid-soluble potash act through the total potash (transposing "Total" and "Active" in Figure 7), the values secured are as follows:

c (total potash)	=0.194
b (acid-soluble potash)	=0.007
a (active potash)	= .666
O (other factors)	= .591

Under either assumption the amount of active potash is decidedly the most important, total potash is of low importance, while acid-soluble is insignificant. "Other factors" are decidedly more important than the amounts of either total or acid-soluble potash in the soil.

The figures obtained apply only to the results as diagrammed. They do not check the conceptions of the causal relations existing between these variables. If the conception of those relations is correct the figures will measure the relative importance of those relations. If the conception of those relations is incorrect, or if the relations are far from linear, the figures will not reveal it unless they are manifestly absurd. These methods are useful primarily for measuring causes; not for deducing them in the first place.

While this mathematical solution is dependent upon the correctness of the premises on which it is based, it affords evidence that is significant. Active potash appears to be the most important factor, and next to it come other factors than the quantity of potash in the soil.

SUMMARY OF CORRELATION FACTORS

Table 9 contains a summary of the correlation factors for purposes of comparison.

Table 9.—Summary of correlation coefficients (all positive)

	Active	Acid Soluble	Acid Insoluble	Total
Potash in two crops	.794 ± .014	.667 ± .023	.388 ± .052	.622 ± .023
Active potash	....	.761 ± .019	.428 ± .034	.625 ± .038
Acid soluble	....	....	....	.792 ± .020
Total potash	....	....	.845 ± .012	....
Potash in first crop	.742 ± .019			
Weight dry matter in first crop	.045 ± .055			
Per cent potash in first crop	.194 ± .053			

ESTIMATION OF ACTIVE POTASH PREFERABLE

The amount of active potash is much more closely related to the potash removed by crops in the pot experiments here reported, than is the acid-soluble, the total, or the acid-insoluble potash. This is brought out by the high correlation factor (r), by the diagrams of Figures 1 and 2, by the standard deviation from the calculated figures, and by the path coefficient for active potash.

The estimation of active potash is also to be preferred on analytical grounds. Since much larger quantities of soil can be used (80 grams) than in the other two methods (0.5 to 2.0 grams) a greater degree of accuracy can be secured in the work. The accuracy of the estimation of total potash leaves much to be desired when 0.5 grams is weighed out directly from the sample not previously ground to an impalpable powder. The estimation of acid-soluble potash is also less accurate in percentage of the amount of potash determined, than is the estimation of active potash.

The relations between the active potash and the potash removed by crops are most clearly brought out when a sufficient number of soils of widely varying potash contents are used. When a small number of soils is used, or when the potash content of the soils is close together, the relations may be obscured by other factors than the quantity of potash present. The mathematical discussion in a preceding section brought out the fact that the operation of other factors might be more significant than the net operation of the amount of either the total potash or the acid-soluble potash, though much less than for the active potash.

CORN POSSIBILITY OF SOIL POTASH

The comparison of the relative deficiency of phosphoric acid, nitrogen and potash in the soil, as brought out by chemical analysis, has been made in previous bulletins by means of the corn possibility. By corn possibility is meant the number of bushels of corn that would be produced from the plant food considered, from two million pounds of soil to the acre, if 0.625 pounds of phosphoric acid, 1.5 pounds of nitrogen or one pound of potash were required to produce one bushel of corn. This method is believed to bring out the relative deficiency of the soil more clearly than a direct comparison of parts per million of plant food, for the reason that there is considerable difference in the amounts of the three plant foods used by the same crop.

The corn possibility is used merely as a method of comparing the amounts of the different plant food present, and is not intended to designate what the soil will produce in the field. Other factors enter into field production.

The figures for corn possibility for active potash based upon the results presented in this Bulletin, and the curve $y = 15x - .0004x^2$ (Figure 2), are given in Table 10. They may be compared with the figures previously used. Since this curve represents two crops, the figures are divided by two. The use of the active potash is to be preferred for the reasons already given.

The corn possibility for acid-soluble potash may be secured by dividing by 2 the calculated values for two crops in Table 5. The corn possibility for total potash may be secured in the same way from Table 11.

DETAILED METHODS OF ANALYSIS

Active Potash and Acid Consumed

Weigh 100 grams of soil into a dry $2\frac{1}{4}$ liter bottle. Heat the water bath to 40° C. Add exactly 1000 cc. 0.2N nitric acid, and place in the warm water bath. Keep the temperature of the bath constant at 40° for the five hours, shaking every half hour. Filter on a large double

Table 10.—Corn possibility of one crop for active potash in two million pounds soil

Group (Active Potash)	Bushels Per Acre
25–50	26
50.1–75	38
75.1–100	50
100.1–125	61
125.1–150	73
150.1–175	84
175.1–200	94
200.1–225	105
225.1–250	115
250.1–275	125
275.1–300	135
300.1–325	144
325.1–350	154
350.1–375	163
375.1–400	171
400.1–425	180
425.1–450	188
450.1–475	196
475.1–500	204
500.1–525	211
525.1–550	219
550.1–575	226
575.1–600	232
600.1–625	239
625.1–650	245
650.1–675	251
675.1–700	256
700.1–725	262
725.1–750	268
750.1–775	273
775.1–800	277
800.1–825	282
825.1–850	286
850.1–875	290
875.1–900	294
900.1–925	297
925.1–950	301
950.1–975	304
975.1–1000 up	306

fluted filter paper. When cold, measure 800 cc. into porcelain evaporating dishes, and save the remaining solution for the determination of acid consumed.

Acid consumed. Dilute 100 cc. with about 50 cc. distilled water and heat to boiling about one minute to expel carbon dioxide. Titrate with 0.1N sodium hydroxide and phenolphthalein. Make a blank on the original acid. Subtract the titration from the blank and multiply by 5. This gives the acid consumed in percentage of 0.2N nitric acid.

Active potash. Evaporate 800 cc. of the filtrate in a large dish transfer to a small dish, add about 20 cc. hydrochloric acid and evaporate to complete dryness in a water bath. Dry thoroughly in an air bath, but do not heat hot enough to decompose the iron salts. Take up with hot water and 5 cc. hydrochloric acid. Filter into an evaporating dish and wash the filter and residue with hot water.

Add 15 cc. hydrochloric acid, evaporate to a small volume, add water enough to make volume about 50 cc. and then add 7 cc. of platinum chloride solution (1 cc. = 1 per cent potash on 1 gram). Evaporate to dryness on a steam bath, or, if this is not possible, to a thick paste. It is not always possible to evaporate to dryness because calcium chloride is sometimes present.

Remove and cool. If it is necessary to keep the material over night, either place the dishes in a special desiccator, or else evaporate again the water absorbed during the night. If the mass becomes black on account of reduction of platinum, add 3 cc. concentrated acid and 10 cc. concentrated hydrochloric acid, cover with a watch glass until action has stopped, and again evaporate. Do not, however, mistake the color of iron salts for reduced platinum.

Add 10 to 30 cc. acid alcohol (see below) stirring while adding. The quantity of alcohol to be used depends on the quantity of salts in the dish. If the mixture becomes very hot when the alcohol is added, which sometimes occurs, though seldom, add quickly 20 to 30 c.c. more alcohol. Stir well and break up lumps with a short stirring rod.

Decant the liquid through asbestos in a gooch crucible. Wash three or four times with acid alcohol, or more if there is much material to be dissolved. Then wash by decantation with 95 per cent alcohol until the alcohol does not dissolve any more colored material. This will take 6 to 12 washes with the 95 per cent alcohol. All the platinum chloride must be removed, for any left will form insoluble ammonium platinum chloride in the next series of washings.

Pour about 10 cc. ammonnium chloride solution on the material in the dish, stir well and allow to stand a few minutes to dissolve the impurities. Pour off through the gooch crucibles, and wash by decantation three times with ammonium chloride solution and as many more as is necessary to remove all the impurities from the yellow platinum salt. The salt should be kept in the dish as far as possible up to this point, as it is more difficult to wash out the impurities from the crucible.

Transfer the yellow precipitate to the crucible with alcohol, carefully rubbing out the dish with a policeman, and wash in the crucible eight times with 95 per cent alcohol, being careful to wash all parts of the inside of the crucible, so as to wash out the ammonium chloride. Examine the precipitate to see that it appears pure before stopping.

Wash the outside of the crucible with alcohol, dry in a steam oven 2-3 hours, and weigh within an hour.

Report parts per million of active potash.

The filtrate from the platinum is run into special flasks which are used for nothing else. The platinum salts are carefully saved. Save all platinum waste and mix nothing else with it.

Acid-Soluble Potash in Soils

Weigh 10 grams of soil into a small pyrex Erlenmeyer flask provided with a rubber stopper carrying a glass tube about 6 inches long. Add 100 c.c. hydrochloric acid 1.115 sp. gr. measured with a pipette, and digest 10 hours in a boiling water bath, shaking every hour. The digestion should be continuous, if possible. Dilute as soon as the digestion is complete with 100 c.c. water, and filter on an ashless filter paper.

Wash the insoluble residue with hot water until free from chlorides, at least 15 times.

Combine the washings and the original solution, and evaporate in a porcelain dish on the steam bath. When nearly dry, add a few drops of nitric acid to oxidize the organic matter. Evaporate to complete dryness, and heat in air bath for 1 hour at 120-130° to render silica insoluble. When cool, add a few drops of strong hydrochloric acid, sufficient only to saturate the residue. Add 10 to 20 cc. of water, warm on the water bath until solution is complete, and the residue is colorless and free from iron and filter, washing 15 times with hot water into a graduated flask. Make the filtrate up to 500 cc. Combine the two filters and main residue, and after drying ignite in a weighed quartz crucible, over a Bunsen flame, for an hour or more; then complete by igniting to constant weight. Weigh and calculate percentage of insoluble residue on Form 170. (This solution is used also for estimation of lime, magnesia, and iron and alumina.)

Measure out 100 cc. of the solution into a porcelain dish, add 10 cc. concentrated hydrochloric acid and evaporate to dryness. Take up with water, add 2 cc. of platinum chloride solution (1 cc. = 1 per cent K_2O), and 2 or 3 cc. hydrochloric acid and evaporate on a water bath to dryness or a thick paste. It is not always possible to get the residue completely dry on account of the presence of calcium chloride, but it can be evaporated to a thick paste. Record on the report sheets the quantity of platinum solution used.

Remove and let it become cold. Add 10 to 30 cc. acid alcohol according to the quantity of material in the dish. All except the potassium platinum chloride should dissolve. Pour the acid alcohol through asbestos in a gooch crucible. Wash again with acid alcohol by decantation, then with 95 per cent alcohol until the alcohol wash does not dissolve any more colored material. Pour the washings through the weighed gooch, but leave the precipitate in the dish as completely as possible. Six washings or more are necessary. Then pour on 10 cc. ammonium chloride wash, stir well, and allow it to stand a few minutes in order to dissolve the impurities. Pour off the wash liquor through the gooch. Wash three times with ammonium chloride by decantation, or as many more times as is necessary to remove all the foreign material, which is usually white in color. Transfer the potash salt to the gooch with 95 per cent alcohol and wash on gooch eight times with alcohol. Remember that a concentrated solution of ammonium chloride has been used, and be careful to wash the sides of the crucible.

Examine the precipitate carefully to see that it consists entirely of potassium platinum chloride. Dry in steam oven, cool in desiccator, and weigh.

The first evaporation is to get rid of nitrates. If any nitrates are present, compounds are formed with the platinum which are not soluble, and vitiate the results.

Total Potash in Soils. Lawrence-Smith Method

Weigh carefully 0.500 grm. and grind to a very fine powder in an agate mortar. Then mix with 0.5 grams ammonium chloride in a glass mortar by use of a spatula and glass pestle; add 4 grams (approximately) C. P. calcium carbonate and mix thoroughly with the preceding mixture by use of a spatula and glass pestle. The mixture is then transferred to a platinum crucible, and inserted in an asbestos board so that about one-third of the crucible is through the hole. Then heat gently. A platinum cover is placed on the crucible, slightly to one side. When the ammonia has volatilized, increase the heat. The flame should be so regulated that the crucible will not be red more than one-half of the height of the fusing mass within the crucible. Heat to low redness for one hour.

Place the crucible, lid, and contents while hot in about 75 cc. water in a 200 cc. beaker, crush the lumps and let stand over night or two hours. Crush lumps in crucibles; if crushed in a beaker, use a pestle, as a glass rod will often punch holes through the beaker. The material should be completely covered. Filter, and wash with hot water at least fifteen times. Evaporate the filtrate to about 50 cc. Filter into a 100 cc. porcelain dish and wash ten times with small amounts of hot water, each time allowing all of the water to run through before adding more, and washing the filter paper near the top. Discard the precipitate, which is carbonate of lime.

Transfer the solution to a porcelain dish, make acid with hydrochloric acid and evaporate to about 50 cc., add 2 cc. of platinum chloride solution (1 cc. = 1 per cent K_2O) and 2 or 3 cc. hydrochloric acid and evaporate on a water bath to dryness. Record on your report sheets the quantity of platinum solution used.

Remove and let cool. Add 10 to 15 cc. acid alcohol. All except the potassium platinum chloride should dissolve. Wash once with acid alcohol, then with 95 per cent alcohol by decantation until the alcohol wash does not dissolve any more colored material of any kind, pouring the washings through a weighed porcelain gooch crucible, but leaving the precipitate in the dish as much as possible. When the soluble platinum salts have been washed out, pour on 10 cc. ammonium chloride wash, stir well, and allow it to stand a few minutes in order to dissolve the impurities. Pour off the wash liquor through the gooch. Wash three times with ammonium chloride by decantation, and as many more times as is necessary to remove all the foreign material. Transfer the potash salt to the gooch crucible with 95 per cent alcohol and wash on gooch eight times with alcohol. Remember that the concentrated solution of ammonium chloride must be washed completely from the inside and outside of crucible. Examine the precipitate carefully to see that it consists entirely of potassium platinum chloride. Dry in steam oven; cool in desiccator and weigh.

Report the results as percentage of total potash (K_2O) in the soil.

Acid alcohol. Add 10 cc. C. P. concentrated hydrochloride acid to 100 cc. 95 per cent alcohol.

SUMMARY AND CONCLUSIONS

(1) The amount of potash removed from the soil by plants depends upon the amount of potash present, the forms of potash, kind of plant, conditions of growth and other factors.

(2) The amount of potash removed from the soil by solvents depends on the amount of potash present, the form of the potash, kind of solvent, fixing power of the soil, conditions of the extraction, and other factors.

(3) Methods of analysis are given for active potash, acid-soluble potash, and total potash in the soil.

(4) When the results are arranged according to the potash removed by the crops, the active potash is found to increase regularly until the potash removed by the crop exceeds 600 parts per million of soil. The total potash and acid-soluble potash increase regularly until the potash removed by the crops exceeds 300 parts per million.

(5) No relation could be traced between the weight of the crop and the active potash in the soil.

(6) The average percentage of potash in the crops increases with the active potash in the soil.

(7) The analysis of the crop for potash is always necessary when the availability of potash to crops is being studied, as the weight of dry matter alone may give misleading results.

(8) There is a close relation between the potash taken up by the crops and the active potash of the soil, the coefficient of correlation being $+.742 \pm .019$ for the first crop and $+.794 \pm .014$ for the two crops.

(9) Curves are drawn for the relation of the active potash to the potash removed by crops, and the percentile deviation from the calculated values shown to average about 30 per cent.

(10) The acid-soluble potash is related to the potash taken up by the crops, the coefficient of correlation being $+.667 \pm .013$ for two crops. The correlation between the active potash and the acid-soluble potash is $+.761 \pm .019$.

(11) Curves are assumed and calculated values compared for the acid-soluble potash and the potash removed by crops, the average percentile deviation from the calculated values being about 44 per cent.

(12) The total potash is related to the potash removed by crops, the coefficient of correlation between total potash and potash in two crops being $+.662 \pm .023$. It is also related to the active potash and to the acid-soluble potash, the correlation coefficients being $+.630 \pm .038$ and $+.792 \pm .020$, respectively.

(13) Curves are assumed and calculated values compared for the total potash and the potash removed by crops, the average percentile deviation from the calculated values being about 45 per cent.

(14) The acid-insoluble potash is less closely related to the potash removed by the crops than the others, the correlation coefficient between acid-insoluble potash and potash in two crops being $+.388 \pm .052$.

(15) If it is assumed that the total potash and the acid-soluble potash act through the active potash as well as directly, the path coefficient for active potash is $+.669$, for total potash $+.189$, for acid-soluble $+.013$, and for other factors $+.520$.

(16) The active potash is most closely related to the results of pot experiments and is best adapted to show the needs or strength of the soil as regards potash.

(17) The corn possibility for potash is used to designate the number of bushels of corn that would be produced under the conditions of the pot experiments from the potash removed if it takes one pound potash for one bushel of corn. It is used to compare the relative deficiency of the soil in phosphoric acid, potash, or nitrogen. Revised figures for corn possibility for potash are given.

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